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(54) Title: MODIFIED PROTEIN KINASE A-SPECIFIC OLIGONUCLEOTIDES AND METHODS OF THEIR USE		
(57) Abstract <p>Disclosed are synthetic, modified oligonucleotides complementary to, and capable of down-regulating the expression of, nucleic acid encoding protein kinase A subunit RIα. The modified oligonucleotides have from about 15 to about 30 nucleotides and are hybrid, inverted hybrid, or inverted chimeric oligonucleotides. Also disclosed are therapeutic compositions containing such oligonucleotides and methods of using the same.</p>		

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**MODIFIED PROTEIN KINASE A-SPECIFIC
OLIGONUCLEOTIDES AND METHODS OF THEIR USE**

FIELD OF THE INVENTION

5 The present invention relates to cancer therapy. More specifically, the present invention relates to the inhibition of the proliferation of cancer cells using modified antisense oligonucleotides complementary to nucleic acid encoding the protein kinase A RI_α subunit.

10 **BACKGROUND OF THE INVENTION**

15 The development of effective cancer therapies has been a major focus of biomedical research. Surgical procedures have been developed and used to treat patients whose tumors are confined to particular anatomical sites. However, at presentation, only about 25% of patients have tumors that are truly confined and amenable to surgical treatment alone (Slapak et al. in Harrison's Principles of Internal Medicine (Isselbacher et al., eds.) McGraw-Hill, Inc., NY (1994) pp. 1826-1850). Radiation therapy, like surgery, is a local modality whose usefulness in the treatment of cancer depends to a large extent on the inherent radiosensitivity of the tumor and its adjacent normal tissues. However, radiation therapy is associated with both acute toxicity and long term sequelae. Furthermore, radiation therapy is known to be mutagenic, carcinogenic, and teratogenic (Slapak et al., *ibid.*).

20

25

30

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Systemic chemotherapy alone or in combination with surgery and/or radiation therapy is currently the primary treatment available for disseminated malignancies. However, conventional

5 chemotherapeutic agents which either block enzymatic pathways or randomly interact with DNA irrespective of the cell phenotype, lack specificity for killing neoplastic cells. Thus, systemic toxicity often results from standard

10 cytotoxic chemotherapy. More recently, the development of agents that block replication, transcription, or translation in transformed cells, and at the same time defeat the ability of cells to become resistant, has been the goal of

15 many approaches to chemotherapy.

One strategy is to down regulate the expression of a gene associated with the neoplastic phenotype in a cell. A technique for

20 turning off a single activated gene is the use of antisense oligodeoxynucleotides and their analogues for inhibition of gene expression (Zamecnik et al. (1978) *Proc. Natl. Acad. Sci. (USA)* 75:280-284). An antisense oligonucleotide

25 targeted at a gene involved in the neoplastic cell growth should specifically interfere only with the expression of that gene, resulting in arrest of cancer cell growth. The ability to specifically block or down-regulate expression of such genes

30 provides a powerful tool to explore the molecular basis of normal growth regulation, as well as the opportunity for therapeutic intervention (see, e.g., Cho-Chung (1993) *Curr. Opin. Thera. Patents* 3:1737-1750). The identification of genes that confer a

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growth advantage to neoplastic cells as well as other genes causally related to cancer and the understanding of the genetic mechanism(s) responsible for their activation makes the antisense approach to cancer treatment possible.

One such gene encodes the RI_{α} subunit of cyclic AMP (cAMP)-dependent protein kinase A (PKA) (Krebs (1972) *Curr. Topics Cell. Regul.* 5:99-133).

Protein kinase is bound by cAMP, which is thought to have a role in the control of cell proliferation and differentiation (see, e.g., Cho-Chung (1980) *J. Cyclic Nucleotide Res.* 6:163-167).

There are two types of PKA, type I (PKA-I) and type II (PKA-II), both of which share a common C subunit but each containing distinct R subunits, RI and RII, respectively (Beebe et al. in *The Enzymes: Control by Phosphorylation*, 17(A):43-111 (Academic, New York, 1986). The R subunit isoforms differ in tissue distribution (Øyen et al. (1988) *FEBS Lett.* 229:391-394; Clegg et al. (1988) *Proc. Natl. Acad. Sci. (USA)* 85:3703-3707) and in biochemical properties (Beebe et al. in *The Enzymes: Control by Phosphorylation*, 17(A):43-111 (Academic Press, NY, 1986); Cadd et al. (1990) *J. Biol. Chem.* 265:19502-19506). The two general isoforms of the R subunit also differ in their subcellular localization: RI is found throughout the cytoplasm; whereas RI localizes to nuclei, nucleoli, Golgi apparatus and the microtubule-organizing center (see, e.g., Lohmann in *Advances in Cyclic Nucleotide and Protein Phosphorylation Research*, 18:63-117

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(Raven, New York, 1984; and Nigg et al. (1985) *Cell* 41:1039-1051).

5 An increase in the level of RI_α expression
has been demonstrated in human cancer cell lines
and in primary tumors, as compared with normal
counterparts, in cells after transformation with
the Ki-*ras* oncogene or transforming growth factor-
α, and upon stimulation of cell growth with
10 granulocyte-macrophage colony-stimulating factor
(GM-CSF) or phorbol esters (Lohmann in *Advances in
Cyclic Nucleotide and Protein Phosphorylation Research*, 18:63-117
(Raven, New York, 1984); and Cho-Chung (1990)
Cancer Res. 50:7093-7100). Conversely, a decrease
15 in the expression of RI_α has been correlated with
growth inhibition induced by site-selective cAMP
analogs in a broad spectrum of human cancer cell
lines (Cho-Chung (1990) *Cancer Res.* 50:7093-7100).
It has also been determined that the expression of
20 RI/PKA-I and RII/PKA-II has an inverse
relationship during ontogenic development and cell
differentiation (Lohmann in *Advances in Cyclic Nucleotide
and Protein Phosphorylation Research*, Vol. 18, 63-117
(Raven, New York, 1984); Cho-Chung (1990) *Cancer
25 Res.* 50:7093-7100). The RI_α subunit of PKA has
thus been hypothesized to be an ontogenic growth-
inducing protein whose constitutive expression
disrupts normal ontogenic processes, resulting in
a pathogenic outgrowth, such as malignancy
30 (Nesterova et al. (1995) *Nature Medicine* 1:528-533).

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Antisense oligonucleotides directed to the RI α gene have been prepared. U.S. Patent No. 5,271,941 describes phosphodiester-linked antisense oligonucleotides complementary to a region of the first 100 N-terminal amino acids of RI α which inhibit the expression of RI α in leukemia cells *in vitro*. In addition, antisense phosphorothioate oligodeoxynucleotides corresponding to the N-terminal 8-13 codons of the RI α gene was found to reduced *in vivo* tumor growth in nude mice (Nesterova et al. (1995) *Nature Med.* 1:528-533).

Unfortunately, problems have been encountered with the use of phosphodiester-linked (PO) oligonucleotides and some phosphorothioate-linked (PS) oligonucleotides. It is known that nucleases in the serum readily degrade PO oligonucleotides. Replacement of the phosphodiester internucleotide linkages with phosphorothioate internucleotide linkages has been shown to stabilize oligonucleotides in cells, cell extracts, serum, and other nuclease-containing solutions (see, e.g., Bacon et al. (1990) *Biochem. Biophys. Meth.* 20:259) as well as *in vivo* (Iversen (1993) *Antisense Research and Application* (Crooke, ed) CRC Press, 461). However, some PS oligonucleotides have been found to exhibit an immunostimulatory response, which in certain cases may be undesirable. For example, Galbraith et al. (*Antisense Res. & Dev.* (1994) 4:201-206) disclose complement activation by some PS oligonucleotides. Henry et al. (*Pharm. Res.* (1994) 11: PPDM8082) disclose that some PS

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oligonucleotides may potentially interfere with blood clotting.

5 There is, therefore, a need for modified oligonucleotides directed to cancer-related genes that retain gene expression inhibition properties while producing fewer side effects than conventional oligonucleotides.

10 SUMMARY OF THE INVENTION

 The present invention relates to modified oligonucleotides useful for studies of gene expression and for the antisense therapeutic
15 approach. The invention provides modified oligonucleotides that down-regulate the expression of the RI_α gene while producing fewer side effects than conventional oligonucleotides. In
20 particular, the invention provides modified oligonucleotides that demonstrate reduced mitogenicity, reduced activation of complement and reduced antithrombotic properties, relative to conventional oligonucleotides.

25 It is also known that some PS oligonucleotides cause an immunostimulatory response in subjects to whom they have been administered, which may be undesirable in some cases.

30 It is known that exclusively phosphodiester- or exclusively phosphorothioate-linked oligonucleotides directed to the first 100

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nucleotides of the RI_α nucleic acid inhibit cell proliferation.

5 It has now been discovered that modified oligonucleotides complementary to the protein kinase A RI_α subunit gene inhibit the growth of tumors *in vivo*. With at least the activity of a comparable PO- or PS-linked oligonucleotide with fewer side effects.

10

This finding has been exploited to produce the present invention, which in a first aspect, includes synthetic hybrid, inverted hybrid, and inverted chimeric oligonucleotides and
15 compositions of matter for specifically down-regulating protein kinase A subunit RI_α gene expression with reduced side effects. Such inhibition of gene expression is useful as an alternative to mutant analysis for determining the
20 biological function and role of protein kinase A-related genes in cell proliferation and tumor growth. Such inhibition of RI_α gene expression can also be used to therapeutically treat diseases and disorders that are caused by the over-
25 expression or inappropriate expression of the gene.

As used herein, the term "synthetic oligonucleotide" includes chemically synthesized
30 polymers of three up to 50, preferably from about 15 to about 30, and most preferably, 18 ribonucleotide and/or deoxyribonucleotide monomers connected together or linked by at least one, and

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preferably more than one, 5' to 3' internucleotide linkage.

For purposes of the invention, the term

5 "oligonucleotide sequence that is complementary to a genomic region or an RNA molecule transcribed therefrom" is intended to mean an oligonucleotide that binds to the nucleic acid sequence under physiological conditions, e.g., by Watson-Crick

10 base pairing (interaction between oligonucleotide and single-stranded nucleic acid) or by Hoogsteen base pairing (interaction between oligonucleotide and double-stranded nucleic acid) or by any other means including in the case of a oligonucleotide

15 binding to RNA, causing pseudoknot formation. Binding by Watson-Crick or Hoogsteen base pairing under physiological conditions is measured as a practical matter by observing interference with the function of the nucleic acid sequence.

20

In one preferred embodiment according to this aspect of the invention, the oligonucleotide is a core region hybrid oligonucleotide comprising a region of at least two deoxyribonucleotides,

25 flanked by 5' and 3' ribonucleotide regions, each having at least four ribonucleotides. A hybrid oligonucleotide having the sequence set forth in the Sequence Listing as SEQ ID NO:4 is one particular embodiment. In some embodiments,

30 each of the 3' and 5' flanking ribonucleotide regions of an oligonucleotide of the invention comprises at least four contiguous, 2'-O-substituted ribonucleotides.

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For purposes of the invention, the term "2'-O-substituted" means substitution of the 2' position of the pentose moiety with an -O- lower alkyl group containing 1-6 saturated or
5 unsaturated carbon atoms, or with an -O-aryl or allyl group having 2-6 carbon atoms, wherein such alkyl, aryl or allyl group may be unsubstituted or may be substituted, e.g., with halo, hydroxy, trifluoromethyl, cyano, nitro, acyl, acyloxy,
10 alkoxy, carboxyl, carbalkoxyl, or amino groups; or with a hydroxy, an amino or a halo group, but not with a 2'-H group.

In some embodiments, each of the 3' and 5' flanking ribonucleotide regions of an
15 oligonucleotide of the invention comprises at least one 2'-O-alkyl substituted ribonucleotide. In one preferred embodiment, the 2'-O-alkyl-substituted nucleotide is a 2'-O-methyl
20 ribonucleotide. In other preferred embodiments, the 3' and 5' flanking ribonucleotide regions of an oligonucleotide of the invention comprises at least four 2'-O-methyl ribonucleotides. In preferred embodiments, the ribonucleotides and
25 deoxyribonucleotides of the hybrid oligonucleotide are linked by phosphorothioate internucleotide linkages. In particular embodiments, this phosphorothioate region or regions have from about four to about 18 nucleosides joined to each other
30 by 5' to 3' phosphorothioate linkages, and preferably from about 5 to about 18 such phosphorothioate-linked nucleosides. The phosphorothioate linkages may be mixed R_p and S_p enantiomers, or they may be stereoregular or

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substantially stereoregular in either R_p or S_p form (see Iyer et al. (1995) *Tetrahedron Asymmetry* 6:1051-1054).

5 In another preferred embodiment according to this aspect of the invention, the oligonucleotide is an inverted hybrid oligonucleotide comprising a region of at least four ribonucleotides flanked by 3' and 5' deoxyribonucleotide regions of at least
10 two deoxyribonucleotides. The structure of this oligonucleotide is "inverted" relative to traditional hybrid oligonucleotides. In some embodiments, the 2'-O-substituted RNA region has from about four to about ten 2'-O-substituted
15 nucleosides joined to each other by 5' to 3' internucleoside linkages, and most preferably from about four to about six such 2'-O-substituted nucleosides. In some embodiments, the oligonucleotides of the invention have a
20 ribonucleotide region comprises at least five contiguous ribonucleotides. In one particularly preferred embodiment, the overall size of the inverted hybrid oligonucleotide is 18. In preferred embodiments, the 2'-O-substituted
25 ribonucleosides are linked to each other through a 5' to 3' phosphorothioate, phosphorodithioate, phosphotriester, or phosphodiester linkages. The phosphorothioate 3' or 5' flanking region (or regions) has from about four to about 18
30 nucleosides joined to each other by 5' to 3' phosphorothioate linkages, and preferably from about 5 to about 18 such phosphorothioate-linked nucleosides. In preferred embodiments, the phosphorothioate regions will have at least 5

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phosphorothioate-linked nucleosides. One specific embodiment is an oligonucleotide having substantially the nucleotide sequence set forth in the Sequence Listing as SEQ ID NO:6. In preferred
5 embodiments of this aspect of the invention, the ribonucleotide region comprise 2'-O-substituted ribonucleotides, such as 2'-O-alkyl substituted ribonucleotides. One particularly preferred embodiment is a hybrid oligonucleotide whose
10 ribonucleotide region comprise at least one 2'-O-methyl ribonucleotide.

In some embodiments, all of the nucleotides in the inverted hybrid oligonucleotide are linked
15 by phosphorothioate internucleotide linkages. In particular embodiments, the deoxyribonucleotide flanking region or regions has from about four to about 18 nucleosides joined to each other by 5' to 3' phosphorothioate linkages, and preferably from
20 about 5 to about 18 such phosphorothioate-linked nucleosides. In some embodiments, the deoxyribonucleotide 3' and 5' flanking regions of the hybrid oligonucleotides of the invention have about 5 phosphorothioate-linked nucleosides. The
25 phosphorothioate linkages may be mixed R_p and S_p enantiomers, or they may be stereoregular or substantially stereoregular in either R_p or S_p form (see Iyer et al. (1995) *Tetrahedron Asymmetry* 6:1051-1054).

30

Another embodiment is a composition of matter for inhibiting the expression of protein kinase A subunit RI_α with reduced side effects, the

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composition comprising an inverted hybrid oligonucleotide according to the invention.

Yet another preferred embodiment according to
5 this aspect of the invention is an inverted
chimeric oligonucleotide comprising an
oligonucleotide nonionic region of at least four
nucleotides flanked by one or more, and preferably
two oligonucleotide phosphorothioate regions.
10 Such a chimeric oligonucleotide has a structure
that is "inverted" relative to traditional
chimeric oligonucleotides. In one particular
embodiment, an inverted chimeric oligonucleotide
of the invention has substantially the nucleotide
15 sequence set forth in the Sequence Listing as SEQ
ID NO:1. In preferred embodiments, the
oligonucleotide nonionic region comprises about
four to about 12 nucleotides joined to each other
by 5' to 3' nonionic linkages. In some
20 embodiments, the nonionic region contains
alkylphosphonate and/or phosphoramidate and/or
phosphotriester internucleoside linkages. In one
particular embodiment, the oligonucleotide
nonionic region comprises six nucleotides. In
25 some preferred embodiments, the oligonucleotide
has a nonionic region having from about six to
about eight methylphosphonate-linked nucleosides,
flanked on either side by phosphorothioate
regions, each having from about six to about ten
30 phosphorothioate-linked nucleosides. In preferred
embodiments, the flanking region or regions are
phosphorothioate nucleotides. In some
embodiments, the flanking region or regions have
from about four to about 24 nucleosides joined to

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each other by 5' to 3' phosphorothioate linkages, and preferably from about six to about 16 such phosphorothioate-linked nucleosides. In preferred
5 embodiments, the phosphorothioate regions have from about five to about 15 phosphorothioate-linked nucleosides. The phosphorothioate linkages may be mixed R_p and S_p enantiomers, or they may be stereoregular or substantially stereoregular in either R_p or S_p form (see Iyer et al. (1995)
10 *Tetrahedron Asymmetry* 6:1051-1054).

Another embodiment of this aspect of the invention is a composition of matter for
15 inhibiting the expression of protein kinase A subunit RI_α with reduced side effects, the composition comprising an inverted chimeric oligonucleotide according to the invention.

Another aspect of the invention is a method
20 of inhibiting the proliferation of cancer cells *in vitro*. In this method, an oligonucleotide of the invention is administered to the cells.

Yet another aspect is a therapeutic
25 composition comprising an oligonucleotide of the invention in a pharmaceutically acceptable carrier.

A method of treating cancer in an afflicted
30 subject with reduced side effects is another aspect of the invention. This method comprises administering a therapeutic composition of the invention to the subject in which the protein kinase A subunit RI_α gene is being over-expressed.

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Those skilled in the art will recognize that the elements of these preferred embodiments can be combined and the inventor does contemplate such combination. For example, 2'-O-substituted
5 ribonucleotide regions may well include from one to all nonionic internucleoside linkages. Alternatively, nonionic regions may have from one to all 2'-O-substituted ribonucleotides. Moreover, oligonucleotides according to the
10 invention may contain combinations of one or more 2'-O-substituted ribonucleotide region and one or more nonionic region, either or both being flanked by phosphorothioate regions. (See *Nucleosides & Nucleotides* 14:1031-1035 (1995) for relevant
15 synthetic techniques.

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BRIEF DESCRIPTION OF THE DRAWINGS

5 The foregoing and other objects of the present invention, the various features thereof, as well as the invention itself may be more fully understood from the following description, when read together with the accompanying drawings in which:

10 FIG. 1 is a graphic representation showing the effect of modified oligonucleotides of the invention on tumor size in a mouse relative to various controls.

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DESCRIPTION OF THE PREFERRED EMBODIMENT

5 The patent and scientific literature referred to herein establishes the knowledge that is available to those with skill in the art. The issued U.S. patents, allowed applications, published foreign applications, and references cited herein are hereby incorporated by reference.

10 Synthetic oligonucleotides of the hybrid, inverted hybrid, and inverted chimeric oligonucleotides as described above.

15 Such synthetic hybrid, inverted hybrid, and inverted chimeric oligonucleotides of the invention have a nucleotide sequence complementary to a genomic region or an RNA molecule transcribed therefore encoding the RI_α subunit of PKA. These oligonucleotides are about 15 to about 30
20 nucleotides in length, preferably about 15 to 25 nucleotides in length, but most preferably, are about 18 nucleotides long. The sequence of this gene is known. Thus, an oligonucleotide of the invention can have any nucleotide sequence
25 complementary to any region of the gene. Three non-limiting examples of an 18mer of the invention has the sequence set forth below in TABLE 1 as SEQ ID NOS:1, 4, and 6.

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TABLE 1

Oligo #	Sequence (5' → 3')	Type	SEQ ID NO:
164	GCG TGC CTC CTC ACT GGC	Control	1'
167	GCG <u>CGC</u> CTC CTC <u>GCT</u> GGC	Mismatched Control	2
188	G <u>CA</u> TGC <u>TTC</u> <u>CAC</u> <u>ACA</u> GGC	Mismatched Control	3
165	*** * * *** GCG UGC CTC CTC ACU GGC	Hybrid	4
168	*** * * *** GCG <u>CGC</u> CTC CTC <u>GCU</u> GGC	Mismatched Hybrid (Control)	5
166	*** ** GCG TGC CUC CUC ACT GGC	Inverted Hybrid	6
169	*** ** GCG <u>CGC</u> CUC CUC <u>GCT</u> GGC	Mismatched Inverted Hybrid (Control)	7
189	*** ** G <u>CA</u> TGC <u>AUC</u> <u>CGC</u> <u>ACA</u> GGC	Mismatched Inverted Hybrid (Control)	8
190 GCG TGC CTC CTC ACT GGC	Inverted Chimeric	1
191 GCG <u>CGC</u> CTC CTC <u>GCT</u> GGC	Mismatched Inverted Chimeric (Control)	2

X = mismatched bases

* ribonucleotide

• methylphosphonate nucleotide

Oligonucleotides having greater than 18 oligonucleotides are also contemplated by the invention. These oligonucleotides have up to 25 additional nucleotides extending from the 3', or 5' terminus, or from both the 3' and 5' termini of, for example, the 18mer with SEQ ID NOS:1, 4,

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or 6, without diminishing the ability of these oligonucleotides to down regulate RI_α gene expression. Alternatively, other oligonucleotides of the invention may have fewer nucleotides than, for example, oligonucleotides having SEQ ID NOS:1, 4, or 6. Such shortened oligonucleotides maintain at least the antisense activity of the parent oligonucleotide to down-regulate the expression of the RI_α gene, or have greater activity.

The oligonucleotides of the invention can be prepared by art recognized methods. Oligonucleotides with phosphorothioate linkages can be prepared manually or by an automated synthesizer and then processed using methods well known in the field such as phosphoramidite (reviewed in Agrawal et al. (1992) *Trends Biotechnol.* 10:152-158, see, e.g., Agrawal et al. (1988) *Proc. Natl. Acad. Sci. (USA)* 85:7079-7083) or H-phosphonate (see, e.g., Froehler (1986) *Tetrahedron Lett.* 27:5575-5578) chemistry. The synthetic methods described in Bergot et al. (*J. Chromatog.* (1992) 559:35-42) can also be used. Examples of other chemical groups include alkylphosphonates, phosphorodithioates, alkylphosphonothioates, phosphoramidates, 2'-O-methyls, carbamates, acetamidate, carboxymethyl esters, carbonates, and phosphate triesters. Oligonucleotides with these linkages can be prepared according to known methods (see, e.g., Goodchild (1990) *Bioconjugate Chem.* 2:165-187; Agrawal et al. (*Proc. Natl. Acad. Sci. (USA)* (1988) 85:7079-7083); Uhlmann et al. (*Chem. Rev.* (1990) 90:534-583;

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and Agrawal et al. (*Trends Biotechnol.* (1992) 10:152-158)).

Preferred hybrid, inverted hybrid, and
5 inverted chimeric oligonucleotides of the
invention may have other modifications which do
not substantially affect their ability to
specifically down-regulate RI_{α} gene expression.
These modifications include those which are
10 internal or are at the end(s) of the
oligonucleotide molecule and include additions to
the molecule at the internucleoside phosphate
linkages, such as cholesteryl or diamine compounds
with varying numbers of carbon residues between
15 the two amino groups, and terminal ribose,
deoxyribose and phosphate modifications which
cleave, or crosslink to the opposite chains or to
associated enzymes or other proteins which bind to
the RI_{α} nucleic acid. Examples of such
20 oligonucleotides include those with a modified
base and/or sugar such as arabinose instead of
ribose, or a 3', 5'-substituted oligonucleotide
having a sugar which, at one or both its 3' and 5'
positions is attached to a chemical group other
25 than a hydroxyl or phosphate group (at its 3' or
5' position). Other modified oligonucleotides are
capped with a nuclease resistance-conferring bulky
substituent at their 3' and/or 5' end(s), or have
a substitution in one or both nonbridging oxygens
30 per nucleotide. Such modifications can be at some
or all of the internucleoside linkages, as well as
at either or both ends of the oligonucleotide
and/or in the interior of the molecule (reviewed

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in Agrawal et al. (1992) *Trends Biotechnol.* 10:152-158).

5 The invention also provides therapeutic
compositions suitable for treating undesirable,
uncontrolled cell proliferation or cancer comprise
at least one oligonucleotide in accordance with
the invention, capable of specifically down-
regulating expression of the RI_{α} gene, and a
10 pharmaceutically acceptable carrier or diluent.
It is preferred that an oligonucleotide used in
the therapeutic composition of the invention be
complementary to at least a portion of the RI_{α}
genomic region, gene, or RNA transcript thereof.

15 As used herein, a "pharmaceutically or
physiologically acceptable carrier" includes any
and all solvents (including but limited to
lactose), dispersion media, coatings,
20 antibacterial and antifungal agents, isotonic and
absorption delaying agents and the like. The use
of such media and agents for pharmaceutically
active substances is well known in the art.
Except insofar as any conventional media or agent
25 is incompatible with the active ingredient, its
use in the therapeutic compositions of the
invention is contemplated. Supplementary active
ingredients can also be incorporated into the
compositions.

30 Several preferred therapeutic composition of
the invention suitable for inhibiting cell
proliferation *in vitro* or *in vivo* or for treating
cancer in humans in accordance with the methods of

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the invention comprises about 25 to 75 mg of a lyophilized oligonucleotide(s) having SEQ ID NOS:1, 4, and/or 6 and 20-75 mg lactose, USP, which is reconstituted with sterile normal saline to the therapeutically effective dosages described herein.

The invention also provides methods for treating humans suffering from disorders or diseases wherein the RI_{α} gene is incorrectly or over-expressed. Such a disorder or disease that could be treated using this method includes tumor-forming cancers such as, but not limited to, human colon carcinoma, breast carcinoma, gastric carcinoma, and neuroblastoma. In the method of the invention, a therapeutically effective amount of a composition of the invention is administered to the human. Such methods of treatment according to the invention, may be administered in conjunction with other therapeutic agents.

As used herein, the term "therapeutically effective amount" means the total amount of each active component of the pharmaceutical formulation or method that is sufficient to show a meaningful subject or patient benefit, i.e., a reduction in tumor growth or in the expression of proteins which cause or characterize the cancer. When applied to an individual active ingredient, administered alone, the term refers to that ingredient alone. When applied to a combination, the term refers to combined amounts of the active ingredients that result in the therapeutic effect,

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whether administered in combination, serially or simultaneously.

5 A "therapeutically effective manner" refers
to a route, duration, and frequency of
administration of the pharmaceutical formulation
which ultimately results in meaningful patient
benefit, as described above. In some embodiments
10 of the invention, the pharmaceutical formulation
is administered via injection, sublingually,
rectally, intradermally, orally, or enterally in
bolus, continuous, intermittent, or continuous,
followed by intermittent regimens.

15 The therapeutically effective amount of
synthetic oligonucleotide in the pharmaceutical
composition of the present invention will depend
upon the nature and severity of the condition
being treated, and on the nature of prior
20 treatments which the patient has undergone.
Ultimately, the attending physician will decide
the amount of synthetic oligonucleotide with which
to treat each individual patient. Initially, the
attending physician will administer low doses of
25 the synthetic oligonucleotide and observe the
patient's response. Larger doses of synthetic
oligonucleotide may be administered until the
optimal therapeutic effect is obtained for the
patient, and at that point the dosage is not
30 increased further. It is contemplated that the
dosages of the pharmaceutical compositions
administered in the method of the present
invention should contain about 0.1 to 5.0 mg/kg
body weight per day, and preferably 0.1 to 2.0

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mg/kg body weight per day. When administered systemically, the therapeutic composition is preferably administered at a sufficient dosage to attain a blood level of oligonucleotide from about 0.01 μM to about 10 μM . Preferably, the concentration of oligonucleotide at the site of aberrant gene expression should be from about 0.01 μM to about 10 μM , and most preferably from about 0.05 μM to about 5 μM . However, for localized administration, much lower concentrations than this may be effective, and much higher concentrations may be tolerated. It may be desirable to administer simultaneously or sequentially a therapeutically effective amount of one or more of the therapeutic compositions of the invention when individual as a single treatment episode.

Administration of pharmaceutical compositions in accordance with invention or to practice the method of the present invention can be carried out in a variety of conventional ways, such as by oral ingestion, enteral, rectal, or transdermal administration, inhalation, sublingual administration, or cutaneous, subcutaneous, intramuscular, intraocular, intraperitoneal, or intravenous injection, or any other route of administration known in the art for administering therapeutic agents.

When the composition is to be administered orally, sublingually, or by any non-injectable route, the therapeutic formulation will preferably include a physiologically acceptable carrier, such

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as an inert diluent or an assimilable edible carrier with which the composition is administered. Suitable formulations that include pharmaceutically acceptable excipients for
5 introducing compounds to the bloodstream by other than injection routes can be found in *Remington's Pharmaceutical Sciences* (18th ed.) (Genarro, ed. (1990) Mack Publishing Co., Easton, PA). The oligonucleotide and other ingredients may be
10 enclosed in a hard or soft shell gelatin capsule, compressed into tablets, or incorporated directly into the individual's diet. The therapeutic compositions may be incorporated with excipients and used in the form of ingestible tablets, buccal
15 tablets, troches, capsules, elixirs, suspensions, syrups, wafers, and the like. When the therapeutic composition is administered orally, it may be mixed with other food forms and pharmaceutically acceptable flavor enhancers.
20 When the therapeutic composition is administered enterally, they may be introduced in a solid, semi-solid, suspension, or emulsion form and may be compounded with any number of well-known, pharmaceutically acceptable additives. Sustained
25 release oral delivery systems and/or enteric coatings for orally administered dosage forms are also contemplated such as those described in U.S. Patent Nos. 4,704,295, 4,556,552, 4,309,404, and 4,309,406.

30

When a therapeutically effective amount of composition of the invention is administered by injection, the synthetic oligonucleotide will preferably be in the form of a pyrogen-free,

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parenterally-acceptable, aqueous solution. The preparation of such parenterally-acceptable solutions, having due regard to ph, isotonicity, stability, and the like, is within the skill in the art. A preferred pharmaceutical composition for injection should contain, in addition to the synthetic oligonucleotide, an isotonic vehicle such as Sodium Chloride Injection, Ringer's Injection, Dextrose Injection, Dextrose and Sodium Chloride Injection, Lactated Ringer's Injection, or other vehicle as known in the art. The pharmaceutical composition of the present invention may also contain stabilizers, preservatives, buffers, antioxidants, or other additives known to those of skill in the art.

The pharmaceutical forms suitable for injectable use include sterile aqueous solutions or dispersions and sterile powders for the extemporaneous preparation of sterile injectable solutions or dispersions. In all cases the form must be sterile. It must be stable under the conditions of manufacture and storage and may be preserved against the contaminating action of microorganisms, such as bacterial and fungi. The carrier can be a solvent or dispersion medium. The prevention of the action of microorganisms can be brought about by various antibacterial and antifungal agents. Prolonged absorption of the injectable therapeutic agents can be brought about by the use of the compositions of agents delaying absorption. Sterile injectable solutions are prepared by incorporating the oligonucleotide in

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the required amount in the appropriate solvent,
followed by filtered sterilization.

5 The pharmaceutical formulation can be
administered in bolus, continuous, or intermittent
dosages, or in a combination of continuous and
intermittent dosages, as determined by the
physician and the degree and/or stage of illness
of the patient. The duration of therapy using the
10 pharmaceutical composition of the present
invention will vary, depending on the unique
characteristics of the oligonucleotide and the
particular therapeutic effect to be achieved, the
limitations inherent in the art of preparing such
15 a therapeutic formulation for the treatment of
humans, the severity of the disease being treated
and the condition and potential idiosyncratic
response of each individual patient. Ultimately
the attending physician will decide on the
20 appropriate duration of intravenous therapy using
the pharmaceutical composition of the present
invention.

25 Compositions of the invention are useful for
inhibiting or reducing the proliferation of cancer
or tumor cells *in vitro*. A synthetic oligonucleotide
of the invention is administered to the cells in
an amount sufficient to enable the binding of the
oligonucleotide to a complementary genomic region
30 or RNA molecule transcribed therefrom encoding the
RI_α subunit. In this way, expression of PKA is
decreased, thus inhibiting or reducing cell
proliferation.

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Compositions of the invention are also useful for treating cancer or uncontrolled cell proliferation in humans. In this method, a therapeutic formulation including an antisense oligonucleotide of the invention is provided in a physiologically acceptable carrier. The individual is then treated with the therapeutic formulation in an amount sufficient to enable the binding of the oligonucleotide to the PKA RI_α genomic region or RNA molecule transcribed therefrom in the infected cells. In this way, the binding of the oligonucleotide inhibits or down-regulates RI_α expression and hence the activity of PKA.

In practicing the method of treatment or use of the present invention, a therapeutically effective amount of at least one or more therapeutic compositions of the invention is administered to a subject afflicted with a cancer. An anticancer response showing a decrease in tumor growth or size or a decrease in RI_α expression is considered to be a positive indication of the ability of the method and pharmaceutical formulation to inhibit or reduce cell growth and thus, to treat cancer in humans.

At least one therapeutic composition of the invention may be administered in accordance with the method of the invention either alone or in combination with other known therapies for cancer such as cisplatin, carboplatin, paclitaxol, tamoxifen, taxol, interferon α and doxorubicin. When co-administered with one or more other

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therapies, the compositions of the invention may be administered either simultaneously with the other treatment(s), or sequentially. If administered sequentially, the attending physician will decide on the appropriate sequence of administering the compositions of the invention in combination with the other therapy.

The following examples illustrate the preferred modes of making and practicing the present invention, but are not meant to limit the scope of the invention since alternative methods may be utilized to obtain similar results.

15

EXAMPLE 1

Synthesis, Deprotection, and Purification of Oligonucleotides

Oligonucleotides were synthesized using standard phosphoramidite chemistry (Beaucage (1993) *Meth. Mol. Biol.* 20:33-61) on an automated DNA synthesizer (Model 8700, Biosearch, Bedford, MA) using a beta-cyanoethyl phosphoramidate approach.

25

Oligonucleotide phosphorothioates were synthesized using an automated DNA synthesizer (Model 8700, Biosearch, Bedford, MA) using a beta-cyanoethyl phosphoramidate approach on a 10 micromole scale. To generate the phosphorothioate linkages, the intermediate phosphite linkage obtained after each coupling was oxidized using 3H, 1,2-benzodithiole-3H-one-1,1-dioxide (see Beaucage, in *Protocols for Oligonucleotides and Analogs: Synthesis and Properties*, Agrawal (ed.), (1993) Humana

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Press, Totowa, NJ, pp. 33-62). Similar synthesis was carried out to generate phosphodiester linkages, except that a standard oxidation was carried out using standard iodine reagent.

5 Synthesis of inverted chimeric oligonucleotide was carried out in the same manner, except that methylphosphonate linkages were assembled using nucleoside methylphosphoramidite (Glen Research, Sterling, VA), followed by oxidation with 0.1 M

10 iodine in tetrahydrofuran/2,6-lutidine/water (75:25:0.25) (see Agrawal & Goodchild (1987) *Tet. Lett.* 28:3539-3542). Hybrids and inverted hybrid oligonucleotides were synthesized similarly, except that the segment containing 2'-O-

15 methylribonucleotides was assembled using 2'-O-methylribonucleoside phosphoramidite, followed by oxidation to a phosphorothioate or phosphodiester linkage as described above. Deprotection and purification of oligonucleotides was carried out

20 according to standard procedures, (see Padmapriya et al. (1994) *Antisense Res. & Dev.* 4:185-199), except for oligonucleotides containing methylphosphonate-containing regions. For those oligonucleotides, the CPG-bound oligonucleotide was treated with

25 concentrated ammonium hydroxide for 1 hour at room temperature, and the supernatant was removed and evaporated to obtain a pale yellow residue, which was then treated with a mixture of

30 ethylenediamine/ethanol (1:1 v/v) for 6 hours at room temperature and dried again under reduced pressure.

EXAMPLE 2

Propagation and Quantitation of Cell Lines

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and Virus Stocks

The cell line utilized was the CEM-SS cell line (Southern Research Institute-Frederick Research Center, Frederick, MD). These cells are highly susceptible to infection with HIV, rapidly form multinucleated syncytia, and are eventually killed by HIV. The cells were maintained ($2-7 \times 10^5$ cells per ml) in RPMI 1640 tissue culture medium supplemented with 10% fetal bovine serum, glutamine, and antibiotics, and were passaged twice weekly at 1:20 dilution. Passage number was logged each week. Cells were discarded after twenty weeks of passage and fresh CEM-SS cells thawed and utilized in the assay. Stocks of CEM-SS cells were frozen in liquid nitrogen in 1 ml NUNC vials in 90% fetal calf serum and 10% dimethyl sulfoxide (DMSO). Following thawing, CEM-SS cells were routinely ready to be utilized in the primary screen assay after two weeks in culture. Prior to replacing a late passage cell line, the new CEM-SS cells were tested in the screening assay protocol utilizing the current stock of infectious virus and AZT. If the infectivity of the virus was significantly different on the new cells or if AZT appeared less active than expected the new cells were not entered into the screening program. Mycoplasma testing was routinely performed on all cell lines.

30

Virus utilized Southern Research Institute-Frederick Research Center. Virus pools were prepared and titrated in CEM-SS cells, placed in 5 ml aliquots, and frozen at -135°C . After thawing, unused virus is discarded to avoid changes in

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infectious titer. Virus pools were prepared by the acute infection of 5×10^5 CEM-SS cells with HIV in a volume of 200 μ l at a multiplicity of infection determined to give complete cell killing at day 7 post-infection (approximately 0.05 for the III_B isolate of HIV-1 and 0.01 for the RF isolate of HIV-1). Infection was allowed to proceed for one hour at 37°C, after which the cells were transferred to a T25 flask and the volume increased to 2 ml. On day 1 post-infection the volume was brought to 5 ml and on day 2 the volume was increased to 10 ml. Beginning on day 4, the cells were pelleted, the supernatant saved, and the cells resuspended in a fresh 10 ml aliquot of tissue culture medium. Complete medium changes on a daily basis, rather than allowing growth of the cells in the medium for longer periods of time, allowed the virus inoculum utilized in the primary screen to remain relatively undepleted of nutrients when it is used to infect cells. The staining reaction utilized (XTT, see method below) required that the glucose concentration remain high (161). Wells depleted of glucose by cell growth will not permit metabolic conversion of the tetrazolium dye to the formazan product.

Cell-free supernatants from the acutely infected cells were saved on day 4, day 5, day 6, and day 7. An aliquot of supernatant was saved separately on each day for use in titer determination. Titer determinations included reverse transcriptase activity assay (see below), endpoint titration or plaque assay (CEM-SS) quantification of infectious particles (see

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below), and quantification of cell killing kinetics.

5 It has been determined that peak levels of
infectious virus are produced in the acutely
infected cultures as the viability of the cells
falls through the 50% level. Since the primary
screening assay quantifies the protective effects
10 of a compound by its ability to inhibit HIV-
induced cytopathic effects, the quantity of virus
required to kill CEM-SS cells in 6 days was
routinely utilized to determine the amount of
virus required per well in the primary screening
assay. Each of the daily pools was titrated in
15 the primary screening tetrazolium dye XTT assay
protocol by performing two-fold dilutions of the
virus beginning at a high test concentration of 50
 μ l of virus per well. The XTT staining method was
utilized to determine the exact amount of virus
20 required to kill all of the CEM-SS cells in each
well and this minimum amount of virus was utilized
for performance of all primary testing. Identical
methods were utilized to prepare all virus
isolates utilized, including laboratory-derived
25 strains of HIV-1, HIV-2 and SIV. Clinical
isolates utilized were passaged in fresh human
cells. The methods for the growth of these cells
and the production of virus pools is described
below.

30

Titer determinations
reverse transcriptase activity assay (see methods
below), endpoint titration or plaque assay (CEM-

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SS) quantification of infectious particles (see methods below), and quantification of cell killing kinetics.

Microtiter Antiviral XTT Assay

5

The tetrazolium dye XTT staining method was utilized to determine the exact amount of virus required to kill all of the CEM-SS cells in each well and this minimum amount of virus was utilized for performance of all primary testing.

10

Cell Preparation:

CEM-SS cells (or other established human cell line used in these experiments) were passaged in T-150 flasks for use in the assay. On the day preceding the assay, the cells were split 1:2 to assure they would be in an exponential growth phase at time of infection. On the day of assay the cells were washed twice with tissue culture medium and resuspended in fresh tissue culture medium. Total cell and viability counting was performed using a hemacytometer and trypan blue dye exclusion. Cell viability was greater than 95% for the cells to be utilized in the assay. The cells were pelleted and resuspended at 2.5×10^4 cells per ml in tissue culture medium. Cells were added to the drug-containing plates in a volume of 50 μ l.

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Virus Preparation:

A pretitered aliquot of virus was removed from the freezer (-80°C) and allowed to thaw slowly to room temperature in a biological safety cabinet. The

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virus was resuspended and diluted into tissue culture medium such that the amount of virus added to each well in a volume of 50 μ l will be the amount determined to give complete cell killing at 6 days post-infection. In general the virus pools produced with the IIIB isolate of HIV required the addition of 5 μ l of virus per well. Pools of RF virus were five to ten-fold more potent, requiring 0.5-1 μ l per well. TCID₅₀ calculation by endpoint titration in CEM-SS cells indicated that the multiplicity of infection of these assays ranged from 0.005-2.5.

Plate Format:

Each plate contained cell control wells (cells only), virus control wells (cells plus virus), drug toxicity control wells (cells plus drug only), drug colorimetric control wells (drug only) as well as experimental wells (drug plus cells plus virus).

XTT Staining of Screening Plates:

After 6 days of incubation at 37°C in a 5% CO₂ incubator the test plates were analyzed by staining with the tetrazolium dye XTT. XTT-tetrazolium is metabolized by the mitochondrial enzymes of metabolically active cells to a soluble formazan product, allowing the rapid quantitative analysis of the inhibition of HIV-induced cell killing by anti-HIV test substances. On day 6 post-infection plates were removed from the incubator and observed. The use of round bottom

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microtiter plates allows rapid macroscopic analysis of the activity of a given test compound by the evaluation of pellet size. The results of the macroscopic observations were confirmed and enhanced by further microscopic analysis.

XTT solution was prepared daily as a stock of 1 mg/ml in PBS. Phenazine methosulfate (PMS) solution was prepared at 15 mg/ml in PBS and stored in the dark at -20°C. XTT/PMS stock was prepared immediately before use by diluting the PMS 1:100 into PBS and adding 40 μ l per ml of XTT solution. Fifty microliters of XTT/PMS was added to each well of the plate and the plate was incubated for an additional 4 hours at 37°C. Adhesive plate sealers were used in place of the lids, the sealed plate was inverted several times to mix the soluble formazan product and the plate was read spectrophotometrically at 450 nm with a Molecular Devices Vmax plate reader. Using an in-house computer program %CPE Reduction, %Cell Viability, IC_{25, 50 & 95}, TC_{25, 50 & 95} and other indices were calculated and the graphic results summary was displayed.

25

b. Reverse Transcriptase Activity Assay:

A microtiter based reverse transcriptase (RT) reaction was utilized (Buckheit et al (1991) *AIDS Research and Human Retroviruses* 7:295-302). Tritiated thymidine triphosphate (NEN) (TTP) was resuspended in distilled H₂O at 5 Ci/ml. Poly rA and oligo dT were prepared as a stock solution which was kept at -20°C. The RT reaction buffer

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was prepared fresh on a daily basis and consists of 125 μ l 1M EGTA, 125 μ l dH₂O, 125 μ l Triton X-100, 50 μ l 1M Tris(pH 7.4), 50 μ l 1M DTT, and 40 μ l 1M MgCl₂. These three solutions were mixed together in a ratio of 1 parts distilled water. Ten microliters of this reaction mixture was placed in a round bottom microtiter plate and 15 μ l of virus containing supernatant was added and mixed. The plate was incubated at 37°C and incubated for 60 minutes. Following reaction, the reaction volume was spotted onto filter mats, washed 6 times for 5 minutes each in a 5% sodium phosphate buffer, 2 times for 1 minute each in distilled water, 2 times for 1 minute each in 70% ethanol, and then dried. The dried filter mat was placed in a plastic sample bag, Betaplate scintillation fluid was added and the bag was heat-sealed. Incorporated radioactivity was quantified utilizing a Wallac Microbeta scintillation counter.

c. p24 ELISA:

ELISA kits were purchased from Coulter. The assay is performed according to the manufacturer's recommendations. Prior to ELISA analysis we routinely performed the reverse transcriptase activity assays (described above) and used the values for incorporated radioactivity in the RT activity assay to determine the dilution of our samples requires for the ELISA. We have constructed standard curves so that the dilutions of virus to be used in the p24 ELISA can be accurately determined from the RT activity assay.

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Control curves are generated in each assay to accurately quantify the amount of capsid protein in each sample. Data was obtained by spectrophotometric analysis at 450 nm using a Molecular Devices Vmax plate reader. P24 concentrations were calculated from the optical density values by use of the Molecular Devices software package Soft Max.

10 d. Infectious Particles:

Infectious virus particles were qualified utilizing the CEM-SS plaque assay as described by Nara, P.L. and Fischinger, P.J. (1988)

15 Quantitative infectivity assay for HIV-1 and HIV-2 (Nature 332:469-470). Flat bottom 96-well microtiter plates (Costar) were coated with 50 μ l of poly-L-lysine (Sigma) at 50 μ g/ml for 2 hours at 37°C. The wells were then washed with PBS and

20 2.5 x 10⁵ CEM-SS cells were placed in the microtiter well where they became fixed to the bottom of the plate. Enough cells were added to form a monolayer of CEM-SS cells in each well. Virus containing supernatant was added from each

25 well of the XTT plate, including virus and cell controls and each serial dilution of the test substance. The number of syncytia were qualified in the flat-bottom 96-well microtiter plate with an Olympus CK2 inverted microscope at 4 days

30 following infection. Each syncytium resulted from a single infectious HIV virion.

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Anti-HIV Activity in Fresh Human Cells: Assay in
Fresh Human T-Lymphocytes

Fresh human peripheral blood lymphocytes (PBL) are isolated from voluntary Red Cross donors, seronegative for HIV and HBV. Leukophoresed blood is diluted 1:1 with Dulbecco's phosphate buffered saline (PBS), layered over 14 mL of Ficoll-Hypaque density gradient in a 50 mL centrifuge tube.

Tubes are then centrifuged for 30 minutes at 600 X

g. Banded PBLs are gently aspirated from the resulting interface and subsequently washed 2X with PBS by low speed centrifugation. After final wash, cells are enumerated by trypan blue

exclusion and re-suspended at 1×10^7 /mL in RPMI

1640 with 15% Fetal Bovine Serum (FBS), 2 mM L-glutamine, 4 mg/mL PHA-P and allowed to incubate for 48 - 72 hours at 37°C. After incubation, PBLs are centrifuged and reset in RPMI 1640 with 15%

FBS, 2 mM L-glutamine, 100 U/mL penicillin, 100

μ g/mL streptomycin, 10 μ g/mL gentamycin, and 20 U/mL recombinant human IL-2. PBLs are maintained in this medium at a concentration of $1-2 \times 10^6$ /mL with bi-weekly medium changes, until use in assay protocol.

For the PBL assay, PHA-P stimulated cells from at least two normal donors are pooled, set in fresh medium at 2×10^6 /mL and plated in the interior wells of a 96 well round bottom microplate at 50

μ L/well. Test drug dilutions are prepared at a 2X concentration in microtiter tubes and 100 μ L of each concentration is placed in appropriate wells in a standard format. Fifty microliters of a predetermined dilution of virus stock is placed in

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each test well. Wells with cells and virus alone are used for virus control. Separate plates are identically set without virus for drug cytotoxicity studies using an XTT assay system.

5

In the standard PBL assay (MOI: 0.2), the assay was ended on day 7 following collection of cell free supernatant samples for reverse transcriptase activity assay. In the low MOI PBL assay (MOI: 10 0.02), supernatant samples were collected on day 6, day 11, and day 14 post-infection and analyzed for RT activity. Tritiated thymidine triphosphate (NEN) (TTP) was resuspended in distilled H₂O at 5 Ci/ml. Poly rA and oligo dT were prepared as a 15 stock solution which was kept at -20°C. The RT reaction buffer was prepared fresh on a daily basis and consists of 125 µl 1M DTT, and 40 µl 1M MgCl₂. These three solutions were mixed together in a ratio of 2 parts TTP, 1 part poly rA:oligo 20 dT, and 1 part reaction buffer. Ten microliters of this reaction mixture was placed in a round bottom microtiter plate and 15 µl of virus containing supernatant was added and mixed. The plate was incubated at 37°C in a water bath with a 25 solid support to prevent submersion of the plate and incubated for 60 minutes. Following reaction, the reaction volume was spotted onto pieces of DE81 paper, washed 5 times for 5 minutes each in a 5% sodium phosphate buffer, 2 times for 1 minute 30 each in distilled water, 2 times for 1 minute each in 70% ethanol, and then dried. Opti-Fluor O was added to each sample and incorporated radioactivity was quantified utilizing a Wallac 1450 Microbetaplug liquid scintillation counter.

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Tritiated thymidine incorporation was measured in parallel cultures at day 7. Each well was pulsed with 1 μ Ci of tritiated thymidine and the cells were harvested 18 hours later with a Skatron cell harvester onto glass fiber filter papers. The filters were dried, placed in a scintillation vial with 1 ml of scintillation cocktail and incorporated radioactivity was quantified on a Packard Tri-Carb 1900 TR liquid scintillation counter.

Anti-HIV Activity in Fresh Human Cells:
Assay in Fresh Human Monocyte-Macrophages

For isolation of adherent cells, 3×10^6 non-PHA stimulated peripheral blood cells were resuspended in Hanks buffered saline (with calcium and magnesium) supplemented with 10% human AB serum. The cells were placed in a 24-well microtiter plate at 37°C for 2 hours. Non-adherent cells were removed by vigorously washing six times. The adherent cells were cultured for 7 days in RPMI 1640 tissue culture medium with 15% fetal bovine serum. The cultures were carefully monitored for confluency during this incubation period. Infection of the cells was performed with the monocyctotropic HIV-1 strains BaL or ADA and the matched pair of AZT-sensitive and AZT-resistant virus isolates. Each of these virus isolates was obtained from the NIAID AIDS Research and Reference Reagent Program. High titer pools of each of these viruses have been harvested from infected cultures of peripheral blood adherent

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cells and frozen in 1.0 ml aliquots at -80°C. Monocyte-macrophage monolayers were infected at an MOI of 0.1. Compounds to be evaluated in the monocyte-macrophage assay are added to the monolayers shortly before infection in order to maximize the potential for identifying active compounds.

At 2 days post-infection, the medium was decanted and the cultures washed twice with complete medium in order to remove excess virus. Fresh medium alone or medium containing the appropriate concentrations of drugs was added and incubation continued for an additional 5 days. XTT-tetrazolium or trypan blue exclusion assays (for cell viability) and HIV p24 ELISA assays (for production of p24 core antigen) were performed on Day 7 post-infection. ELISA kits were purchased from Coulter. The assay is performed according to the manufacturer's recommendations. Control curves are generated in each assay to accurately quantify the amount of capsid protein in each sample. Data was obtained by spectrophotometric analysis at 450 nm using a Molecular Devices Vmax plate reader. P24 concentrations were calculated from the optical density values by use of the Molecular Device software package Soft Max.

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----- To determine the relative effect of inverted hybrid or inverted chimeric structure on

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oligonucleotide-mediated depletion of complement, the following experiments were performed. Venous blood was collected from healthy adult human volunteers. Serum was prepared for hemolytic complement assay by collecting blood into vacutainers (Becton Dickinson #6430 Franklin Lakes, NJ) without commercial additives. Blood was allowed to clot at room temperature for 30 minutes, chilled on ice for 15 minutes, then centrifuged at 4°C to separate serum. Harvested serum was kept on ice for same day assay or, alternatively, stored at -70°C. Buffer, or an oligonucleotide sample was then incubated with the serum. The oligonucleotides tested were 25mer oligonucleotide phosphodiesteres or phosphorothioates, 25mer hybrid oligonucleotides, 25mer inverted hybrid oligonucleotides, 25mer chimeric oligonucleotides, and 25mer inverted chimeric oligonucleotides. Representative hybrid oligonucleotides were composed of seven to 13 2-O-methyl ribonucleotides flanked by two regions of six to nine deoxyribonucleotides each. Representative 25mer inverted hybrid oligonucleotides were composed of 17 deoxyribonucleotides flanked by two regions of four ribonucleotides each. Representative 25mer chimeric oligonucleotides were composed of six methylphosphonate deoxyribonucleotides and 19 phosphorothioate deoxyribonucleotides. Representative inverted chimeric oligonucleotides were composed of from 16 to 17 phosphorothioate deoxyribonucleotides flanked by regions of from two to seven methylphosphonate deoxyribonucleotides, or from six to eight

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methyolphosphonate deoxyribonucleotides flanked by
nine to ten phosphorothioate deoxyribonucleotides,
or two phosphorothioate regions ranging from two
to 12 oligonucleotides, flanked by three
5 phosphorothioate regions ranging in size from two
to six nucleotides in length. A standard CH50
assay (See Kabat and Mayer (eds), *Experimental*
Immunochimistry, 2d Ed., Springfield, IL, CC Thomas,
p. 125) for complement-mediated lysis of sheep red
10 blood cells (Colorado Serum Co.) sensitized with
anti-sheep red blood cell antibody (hemolysin,
Diamedix, Miami, FL) was performed, using
duplicate determinations of at least five
dilutions of each test serum, then hemoglobin
15 release into cell-free supernates was measured
spectrophotometrically at 541 nm.

EXAMPLE 3

In Vitro Mitogenicity Studies

20

To determine the relative effect of inverted
hybrid or inverted chimeric structure on
oligonucleotide-mediated mitogenicity, the
following experiments were performed. Spleen was
25 taken from a male CD1 mouse (4-5 weeks, 20-22 g;
Charles River, Wilmington, MA). Single cell
suspensions were prepared by gently mincing with
frosted edges of glass slides. Cells were then
cultured in RPMI complete media (RPMI media
30 supplemented with 10% fetal bovine serum (FBS), 50
micromolar 2-mercaptoethanol (2-ME), 100 U/ml
penicillin, 100 micrograms/ml streptomycin, 2 mM
L-glutamine). To minimize oligonucleotide
degradation, FBS was first heated for 30 minutes

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at 65°C (phosphodiester-containing oligonucleotides) or 56°C (all other oligonucleotides). Cells were plated in 96 well dishes at 100,000 cells per well (volume of 100 microliters/well). One type of each oligonucleotide described in Example 2 above in 10 microliters TE buffer (10 mM Tris-HCl, pH 7.5, 1 mM EDTA) was added to each well. After 44 hours of culturing at 37°C, one microcurie tritiated thymidine (Amersham, Arlington Heights, IL) was added in 20 microliters RPMI media for a 4 hour pulse labelling. The cells were then harvested in an automatic cell harvester (Skatron, Sterling, VA) and the filters were assessed using a scintillation counter. In control experiments for mitogenicity, cells were treated identically, except that either media (negative control) or concanavalin A (positive control) was added to the cells in place of the oligonucleotides.

All of the inverted hybrid oligonucleotides proved to be less immunogenic than phosphorothioate oligonucleotides. Inverted hybrid oligonucleotides having phosphodiester linkages in the 2'-O-methyl region appeared to be slightly less immunogenic than those containing phosphorothioate linkages in that region. No significant difference in mitogenicity was observed when the 2'-O-methyl ribonucleotide region was pared down from 13 to 11 or to 9 nucleotides. Inverted chimeric oligonucleotides were also generally less mitogenic than phosphorothioate oligonucleotides. In addition, these oligonucleotides appeared to be less

-45-

mitogenic than traditional chimeric oligonucleotides, at least in cases in which the traditional chimeric oligonucleotides had significant numbers of methylphosphonate linkages near the 3' end. Increasing the number of methylphosphonate linkers in the middle of the oligonucleotide from 5 to 6 or 7 did not appear to have a significant effect on mitogenicity. These results indicate that incorporation of inverted hybrid or inverted chimeric structure into an oligonucleotide can reduce its mitogenicity.

EXAMPLE 4

In Vitro Studies

To determine the relative effect of inverted hybrid or inverted chimeric structure on oligonucleotide-induced mitogenicity, the following experiments were performed. Venous blood was collected from healthy adult human volunteers. Plasma for clotting time assay was prepared by collecting blood into siliconized vacutainers with sodium citrate (Becton Dickinson #367705), followed by two centrifugations at 4°C to prepare platelet-poor plasma. Plasma aliquots were kept on ice, spiked with various test oligonucleotides described in Example 2 above, and either tested immediately or quickly frozen on dry ice for subsequent storage at -20°C prior to coagulation assay. Activated partial thromboplastin time (aPTT) was performed in duplicate on an Electra 1000C (Medical Laboratory Automation, Mount Vernon, NY) according to the manufacturer's recommended procedures, using Actin

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FSL (Baxter Dade, Miami, FL) and calcium to initiate clot formation, which was measured photometrically. Prolongation of aPTT was taken as an indication of clotting inhibition side effect produced by the oligonucleotide.

Traditional phosphorothioate oligonucleotides produced the greatest prolongation of aPTT, of all of the oligonucleotides tested. Traditional hybrid oligonucleotides produced somewhat reduced prolongation of aPTT. In comparison with traditional phosphorothioate or traditional hybrid oligonucleotides, all of the inverted hybrid oligonucleotides tested produced significantly reduced prolongation of aPTT. Inverted hybrid oligonucleotides having phosphodiester linkages in the 2'-O-substituted ribonucleotide region had the greatest reduction in this side effect, with one such oligonucleotide having a 2'-O-methyl RNA phosphodiester region of 13 nucleotides showing very little prolongation of aPTT, even at oligonucleotide concentrations as high as 100 micrograms/ml. Traditional chimeric oligonucleotides produce much less prolongation of aPTT than do traditional phosphorothioate oligonucleotides. Generally, inverted chimeric oligonucleotides retain this characteristic. At least one inverted chimeric oligonucleotide, having a methylphosphonate region of seven nucleotides flanked by phosphorothioate regions of nine nucleotides, gave better results in this assay than the traditional chimeric oligonucleotides at all but the highest oligonucleotide concentrations tested. These

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results indicate that inverted hybrid and inverted chimeric oligonucleotides may provide advantages in reducing the side effect of clotting inhibition when they are administered to modulate gene expression *in vivo*.

EXAMPLE 5

In Vivo Complement Activation Studies

Rhesus monkeys (4-9 kg body weight) are acclimatized to laboratory conditions for at least 7 days prior to the study. On the day of the study, each animal is lightly sedated with ketamine-HCl (10 mg/kg) and diazepam (0.5 mg/kg). Surgical level anesthesia is induced and maintained by continuous ketamine intravenous drip throughout the procedure. The oligonucleotides described in Example 2 above are dissolved in normal saline and infused intravenously via a cephalic vein catheter, using a programmable infusion pump at a delivery rate of 0.42 mg/minute. For each oligonucleotide, doses of 0, 0.5, 1, 2, 5 and 10 mg/kg are administered to two animals each over a 10 minute infusion period. Arterial blood samples are collected 10 minutes prior to oligonucleotide administration and 2, 5, 10, 20, 40 and 60 minutes after the start of the infusion, as well as 24 hours later. Serum is used for determining complement CH50, using the conventional complement-dependent lysis of sheep erythrocyte procedure (see Kabat and Mayer, 1961, *supra*). At the highest dose, phosphorothioate oligonucleotide causes a decrease in serum complement CH50 beginning within 5 minutes of the

-48-

start of infusion. Inverted hybrid and chimeric oligonucleotides are expected to show a much reduced or undetectable decrease in serum complement CH50 under these conditions.

5

EXAMPLE 6**In Vivo Mitogenicity Studies**

CD1 mice are injected intraperitoneally with a dose of 50 mg/kg body weight of oligonucleotide described in Example 2 above. Forty-eight hours later, the animals are euthanized and the spleens are removed and weighed. Animals treated with inverted hybrid or inverted hybrid oligonucleotides are expected to show no significant increase in spleen weight, while those treated with oligonucleotide phosphorothioates are expected to show modest increases in spleen weight.

20

EXAMPLE 7**In Vivo Clotting Studies**

Rhesus monkeys are treated as in Example 5. From the whole blood samples taken, plasma for clotting assay is prepared, and the assay performed, as described in Example 4. It is expected that prolongation of aPTT will be substantially reduced for both inverted hybrid oligonucleotides and for inverted chimeric oligonucleotide, relative to traditional oligonucleotide phosphorothioates.

30

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EXAMPLE 8

RNase H Activity Studies

To determine the ability of inverted hybrid
5 oligonucleotides and inverted chimeric
oligonucleotides to activate RNase H when bound to
a complementary RNA molecule, the following
experiments were performed. Each type of
oligonucleotide described in Example 2 above was
10 incubated together with a molar equivalent
quantity of complimentary oligoribonucleotide
(0.266 micromolar concentration of each), in a
cuvette containing a final volume of 1 ml RNase H
buffer (20 mM Tris-HCl, pH 7.5, 10 mM MgCl₂, 0.1 M
15 KCl, 2% glycerol, 0.1 mM DTT). The samples were
heated to 95°C, then cooled gradually to room
temperature to allow annealing to form duplexes.
Annealed duplexes were incubated for 10 minutes at
37°C, then 5 units RNase H was added and data
20 collection commenced over a three hour period.
Data was collected using a spectrophotometer (GBC
920, GBC Scientific Equipment, Victoria,
Australia) at 259 nm. RNase H degradation was
determined by hyperchromic shift.

25
As expected, phosphodiester oligonucleotides
behaved as very good co-substrates for RNase H-
mediated degradation of RNA, with a degradative
half-life of 8.8 seconds. Phosphorothioate
30 oligonucleotides produced an increased half-life
of 22.4 seconds. Introduction of a 2'-O-methyl
ribonucleotide segment at either end of the
oligonucleotide further worsened RNase H activity
(half-life = 32.7 seconds). In contrast,

-50-

introducing a 2'-O-methyl segment into the middle of the oligonucleotide (inverted hybrid structure) always resulted in improved RNase H-mediated degradation. When a region of 13 2'-O-methylribonucleoside phosphodiester was flanked on both sides by phosphorothioate DNA, the best RNase H activity was observed, with a half-life of 7.9 seconds. Introduction of large blocks of methylphosphonate-linked nucleosides at the 3' end of the oligonucleotide either had no effect or caused further deterioration of RNase H activity even when in a chimeric configuration. Introduction of methylphosphonate linked nucleosides at the 5' end, however, improved RNase H activity, particularly in a chimeric configuration with a single methylphosphonate linker at the 3' end (best half-life = 8.1 seconds). All inverted chimeric oligonucleotides with methylphosphonate core regions flanked by phosphorothioate regions gave good RNase results, with a half-life range of 9.3 to 14.4 seconds. These results indicate that the introduction of inverted hybrid or inverted chimeric structure into phosphorothioate-containing oligonucleotides can restore some or all of the ability of the oligonucleotide to act as a co-substrate for RNase H, a potentially important attribute for an effective antisense agent.

EXAMPLE 9

Melting Temperature Studies

To determine the effect of inverted hybrid or inverted chimeric structure on stability of the duplex formed between an antisense oligonucleotide

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and a target molecule, the following experiments were performed. Thermal melting (T_m) data were collected using a spectrophotometer (GBC 920, GBC Scientific Equipment, Victoria, Australia), which
5 has six 10 mm cuvettes mounted in a dual carousel. In the T_m experiments, the temperature was directed and controlled through a peltier effect temperature controller by a computer, using software provided by GBC, according to the
10 manufacturer's directions. T_m data were analyzed by both the first derivative method and the mid-point method, as performed by the software. T_m experiments were performed in a buffer containing 10 mM PIPES, pH 7.0, 1 mM EDTA, 1 M NaCl. A
15 refrigerated bath (VWR 1166, VWR, Boston, MA) was connected to the peltier-effect temperature controller to absorb the heat. Oligonucleotide strand concentration was determined using absorbance values at 260 nm, taking into account
20 extinction coefficients.

EXAMPLE 10

Tumor Growth and Antisense Treatment

25 LS-174T human colon carcinoma cells (1×10^6 cells) were inoculated subcutaneously (s.c.) into the left flank of athymic mice. A single dose of RI_a antisense hybrid (Oligo 164, SEQ ID NO:4),
inverted hybrid (Oligo 166, SEQ ID NO:6), or
30 inverted chimeric (Oligo 190, SEQ ID NO:1)
oligonucleotides or control oligonucleotide (Oligo 169, SEQ ID NO:7); Oligo 168 (SEQ ID NO:5); Oligo 188, SEQ ID NO:3)) as shown in Table 1 (1 mg per 0.1 ml saline per mouse), or saline (0.1 ml per

-52-

mouse), was injected s.c. into the right flank of mice when tumor size reached 80 to 100 mg, about 1 week after cell inoculation. Tumor volumes were obtained from daily measurement of the longest and shortest diameters and calculation by the formula, $4/3\pi r^3$ where $r = (\text{length} + \text{width})/4$. At each indicated time, two animals from the control and antisense-treated groups were killed, and tumors were removed and weighed. The results are shown in FIG. 1. These results show that the size of the tumor in the animal treated with the inverted hybrid oligonucleotide 166 having SEQ ID NO:6 was surprisingly smaller from three days after injection onward than the phosphorothioate oligonucleotide 164 having SEQ ID NO:1. That this effect was sequence-specific is also demonstrated in FIG. 1: control oligonucleotide 168 (SEQ ID NO:3) has little ability to keep tumor size at a minimum relative to the hybrid and inverted hybrid oligonucleotides.

EXAMPLE 11

Photoaffinity Labelling and Immunoprecipitation of RI_α Subunits

25

The tumors are homogenized with a Teflon/glass homogenizer in ice-cold buffer 10 (Tris-HCl, pH 7.4, 20 mM; NaCl, 100 mM; NP-40, 1%; sodium deoxycholate, 0.5%; MgCl₂, 5 mM; pepstatin, 0.1 mM; antipain, 0.1 mM; chymostatin, 0.1 mM; leupeptin, 0.2 mM; aprotinin, 0.4 mg/ml; and soybean trypsin inhibitor, 0.5 mg/ml; filtered through a 0.45- μ m pore size membrane), and

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centrifuged for 5 min in an Eppendorf microfuge at 4°C. The supernatants are used as tumor extracts.

5 The amount of PKA RI_α subunits in tumors is determined by photoaffinity labelling with 8-N₃-[³²P]cAMP followed by immunoprecipitation with RI_α antibodies as described by Tortora et al. (*Proc. Natl. Acad. Sci. (USA)* (1990) 87:705-708). The photoactivated incorporation of 8-N₃-[³²P]cAMP
10 (60.0 Ci/m-mol), and the immunoprecipitation using the anti-RI_α or anti-RII_β antiserum and protein A Sepharose and SDS-PAGE of solubilized antigen-antibody complex follows the method previously described (Tortora et al. (1990) *Proc. Natl. Acad. Sci. (USA)* 87:705-708; Ekanger et al. (1985) *J. Biol. Chem.* 260:3393-3401). It is expected that the amount of RI_α in tumors treated with hybrid, inverted hybrid, and inverted chimeric oligonucleotides of
15 the invention will be reduced compared with the amount in tumors treated with mismatch, straight phosphorothioate, or straight phosphodiester oligonucleotide controls, saline, or other controls.

25

EXAMPLE 12

cAMP-Dependent Protein Kinase Assays

30 Extracts (10 mg protein) of tumors from antisense-, control antisense-, or saline-treated animals are loaded onto DEAE cellulose columns (1 x 10 cm) and fractionated with a linear salt gradient (Rohlf et al. (1993) *J. Biol. Chem.* 268:5774-5782). PKA activity is determined in the absence or presence of 5 μM cAMP as described

-54-

below (Rohlf et al. (1993) *J. Biol. Chem.* 268:5774-5782). cAMP-binding activity is measured by the method described previously and expressed as the specific binding (Tagliaferri et al. (1988) *J. Biol.*
5 *Chem.* 263:409-416).

After two washes with Dulbecco's phosphate-buffered saline, cell pellets (2×10^6 cells) are lysed in 0.5 ml of 20 mM Tris (pH 7.5), 0.1 mM
10 sodium EDTA, 1 mM dithiothreitol, 0.1 mM pepstatin, 0.1 mM antipain, 0.1 mM chymostatin, 0.2 mM leupeptin, 0.4 mg/ml aprotinin, and 0.5 mg/ml soybean trypsin inhibitor, using 100 strokes of a Dounce homogenizer. After centrifugation
15 (Eppendorf 5412) for 5 min, the supernatants are adjusted to 0.7 mg protein/ml and assayed (Uhler et al. (1987) *J. Biol. Chem.* 262:15202-15207) immediately. Assays (40 μ l total volume) are performed for 10 min at 30°C and contained 200 μ M
20 ATP, 2.7×10^6 cpm γ [32 P]ATP, 20 mM MgCl_2 , 100 μ M Kemptide (Sigma K-1127) (Kemp et al. (1977) *J. Biol. Chem.* 252:4888-4894), 40 mM Tris (pH 7.5), \pm 100 μ M protein kinase inhibitor (Sigma P-3294) (Cheng et al. (1985) *Biochem. J.* 231:655-661), \pm 8 μ M cAMP
25 and 7 μ g of cell extract. The phosphorylation of Kemptide is determined by spotting 20 μ l of incubation mixture on phosphocellulose filters (Whatman, P81) and washing in phosphoric acid as described (Roskoski (1983) *Methods Enzymol.* 99:3-6).
30 Radioactivity is measured by liquid scintillation using Econofluor-2 (NEN Research Products NEF-969). It is expected that PKA and cAMP binding activity will be reduced in extracts of tumors

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treated with the hybrid, inverted hybrid, and inverted chimeric oligonucleotides of the invention.

5 EQUIVALENTS

Those skilled in the art will recognize, or be able to ascertain, using no more than routine experimentation, numerous equivalents to the specific substances and procedures described herein. Such equivalents are considered to be within the scope of this invention, and are covered by the following claims.

15

-56-

SEQUENCE LISTING

(1) GENERAL INFORMATION:

- (i) APPLICANT: Agrawal, Sudhir
- (ii) TITLE OF INVENTION: MODIFIED PROTEIN KINASE A-SPECIFIC OLIGONUCLEOTIDES AND METHODS OF THEIR USE
- (iii) NUMBER OF SEQUENCES: 8
- (iv) CORRESPONDENCE ADDRESS:
 - (A) ADDRESSEE: Lappin & Kusmer
 - (B) STREET: 200 State Street
 - (C) CITY: Boston
 - (D) STATE: MA
 - (E) COUNTRY: USA
 - (F) ZIP: 02109
- (v) COMPUTER READABLE FORM:
 - (A) MEDIUM TYPE: Floppy disk
 - (B) COMPUTER: IBM PC compatible
 - (C) OPERATING SYSTEM: PC-DOS/MS-DOS
 - (D) SOFTWARE: PatentIn Release #1.0, Version #1.30
- (vi) CURRENT APPLICATION DATA:
 - (A) APPLICATION NUMBER: US
 - (B) FILING DATE:
 - (C) CLASSIFICATION:
- (viii) ATTORNEY/AGENT INFORMATION:
 - (A) NAME: Kerner, Ann-Louise
 - (B) REGISTRATION NUMBER: 33,523
 - (C) REFERENCE/DOCKET NUMBER: HYZ-050
- (ix) TELECOMMUNICATION INFORMATION:
 - (A) TELEPHONE: 617-330-1300
 - (B) TELEFAX: 617-330-1311

(2) INFORMATION FOR SEQ ID NO:1:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 18 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA

-57-

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

GCGTGCCTCC TCACTGGC

18

(2) INFORMATION FOR SEQ ID NO:2:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 18 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

GCGCGCCTCC TCGCTGGC

18

(2) INFORMATION FOR SEQ ID NO:3:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 18 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

GCATGCTTCC ACACAGGC

18

(2) INFORMATION FOR SEQ ID NO:4:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 18 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single

-58-

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA/RNA

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

GCGUGCCTCC TCACUGGC

18

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 18 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA/RNA

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

GCGCGCCTCC TCGCUGGC

18

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 18 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA/RNA

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

GCGTGCCUCC UCACTGGC

18

(2) INFORMATION FOR SEQ ID NO:7:

(i) SEQUENCE CHARACTERISTICS:

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- (A) LENGTH: 18 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA/RNA

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

GCGCGCCUCC UCGCTGGC

18

(2) INFORMATION FOR SEQ ID NO:8:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 18 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA/RNA

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

GCGCGCCUCC UCGCTGGC

18

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What is claimed is:

1. A synthetic, modified oligonucleotide complementary to, and capable of down-regulating
5 the expression of, nucleic acid encoding protein kinase A subunit RIa, the modified oligonucleotide having from about 15 to about 30 nucleotides and being a hybrid, inverted hybrid, or inverted chimeric oligonucleotide,
10 the hybrid oligonucleotide comprising a region of at least two deoxyribonucleotides, flanked by 3' and 5' flanking ribonucleotide regions each having at least four ribonucleotides,
the inverted hybrid oligonucleotide
15 comprising a region of at least four ribonucleotides flanked by 3' and 5' flanking deoxyribonucleotide regions of at least two deoxyribonucleotides,
and the inverted chimeric oligonucleotide
20 comprising an oligonucleotide nonionic region of at least four nucleotides flanked by two oligonucleotide phosphorothioate regions.
2. The oligonucleotide of claim 1 having 18
25 nucleotides.
3. The oligonucleotide of claim 1 which is a hybrid oligonucleotide.
- 30 4. The oligonucleotide of claim 3 having substantially the nucleotide sequence set forth in SEQ ID NO:4.

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5. The oligonucleotide of claim 3 wherein each of the flanking ribonucleotide regions comprises at least four contiguous 2'-O-substituted ribonucleotides.
- 5 6. The oligonucleotide of claim 5 wherein each of the flanking ribonucleotide regions comprises at least one 2'-O-alkyl ribonucleotide.
- 10 7. The oligonucleotide of claim 6 wherein each of the flanking ribonucleotide regions comprises at least one 2'-O-methyl ribonucleotide.
- 15 8. The oligonucleotide of claim 5 wherein each of the flanking ribonucleotide regions comprises at least four 2'-O-methyl ribonucleotides.
- 20 9. The oligonucleotide of claim 3 wherein the ribonucleotides and deoxyribonucleotides are linked by phosphorothioate internucleotide linkages.
- 25 10. The oligonucleotide of claim 1 which is an inverted hybrid oligonucleotide.
11. The oligonucleotide of claim 10 having substantially the nucleotide sequence set forth in the Sequence Listing as SEQ ID NO:6.
- 30 12. The oligonucleotide of claim 10 wherein the ribonucleotide region comprises at least five contiguous ribonucleotides.

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13. The oligonucleotide of claim 12 wherein the deoxyribonucleotide flanking regions comprise six contiguous ribonucleotides.

5 14. The oligonucleotide of claim 10 wherein the flanking ribonucleotide regions comprise 2'-O-substituted ribonucleotides.

10 15. The oligonucleotide of claim 16 wherein the 2'-O-substituted ribonucleotides is a 2'-O-alkyl substituted ribonucleotide.

15 16. The oligonucleotide of claim 15 wherein each of the flanking ribonucleotide regions comprise at least one 2'-O-methyl ribonucleotide.

20 17. The oligonucleotide of claim 10 wherein the nucleotides are linked by phosphorothioate internucleotide linkages.

25 18. A composition of matter for inhibiting the expression of protein kinase A with reduced side effects, the composition comprising the inverted hybrid oligonucleotide of claim 12.

30 19. The oligonucleotide of claim 1 which is an inverted chimeric oligonucleotide.

20. The oligonucleotide of claim 19 having substantially the nucleotide sequence set forth in the Sequence Listing as SEQ ID NO:1.

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21. The oligonucleotide of claim 19 wherein the oligonucleotide nonionic region comprises about 4 to about 12 nucleotides.
- 5 22. The oligonucleotide of claim 21 wherein the oligonucleotide nonionic region comprises six nucleotides.
- 10 23. The oligonucleotide of claim 19 wherein the oligonucleotide nonionic region comprises alkylphosphonate nucleotides.
- 15 24. The oligonucleotide of claim 23 wherein the oligonucleotide nonionic region comprises methylphosphonate nucleotides.
- 20 25. The oligonucleotide of claim 19 wherein the nucleotides in the flanking regions comprise at least six contiguous nucleotides linked by phosphorothioate internucleotide linkages.
- 25 26. A composition of matter for inhibiting the expression of the protein kinase A RI_α subunit gene with reduced side effects, the composition comprising the inverted chimeric oligonucleotide of claim 19.
- 30 27. A method of inhibiting the proliferation of cancer cells *in vitro* comprising the step of administering the oligonucleotide of claim 1 to the cells.

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28. A method of inhibiting the proliferation of cancer cells *in vitro* comprising the step of administering the oligonucleotide of claim 3 to the cells.

5

29. A method of inhibiting the proliferation of cancer cells *in vitro* comprising the step of administering the oligonucleotide of claim 10 to the cells.

10

30. A method of inhibiting the proliferation of cancer cells *in vitro* comprising the step of administering the oligonucleotide of claim 19 to the cells.

15

31. A therapeutic composition comprising the oligonucleotide of claim 1 in a pharmaceutically acceptable carrier.

20

32. A therapeutic composition comprising the oligonucleotide of claim 3 in a pharmaceutically acceptable carrier.

25

33. A therapeutic composition comprising the oligonucleotide of claim 10 in a pharmaceutically acceptable carrier.

30

34. A therapeutic composition comprising the oligonucleotide of claim 19 in a pharmaceutically acceptable carrier.

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35. A method of treating cancer in an afflicted subject comprising the step of administering to the subject the therapeutic composition of claim 31.

5

36. A method of treating cancer in an afflicted subject comprising the step of administering to the subject the therapeutic composition of claim 32.

10

37. A method of treating cancer in an afflicted subject with reduced side effects, the method comprising the step of administering to the subject the therapeutic composition of claim 33.

15

38. A method of treating cancer in an afflicted subject with reduced side effects, the method comprising the step of administering to the subject the therapeutic composition of claim 34.

20

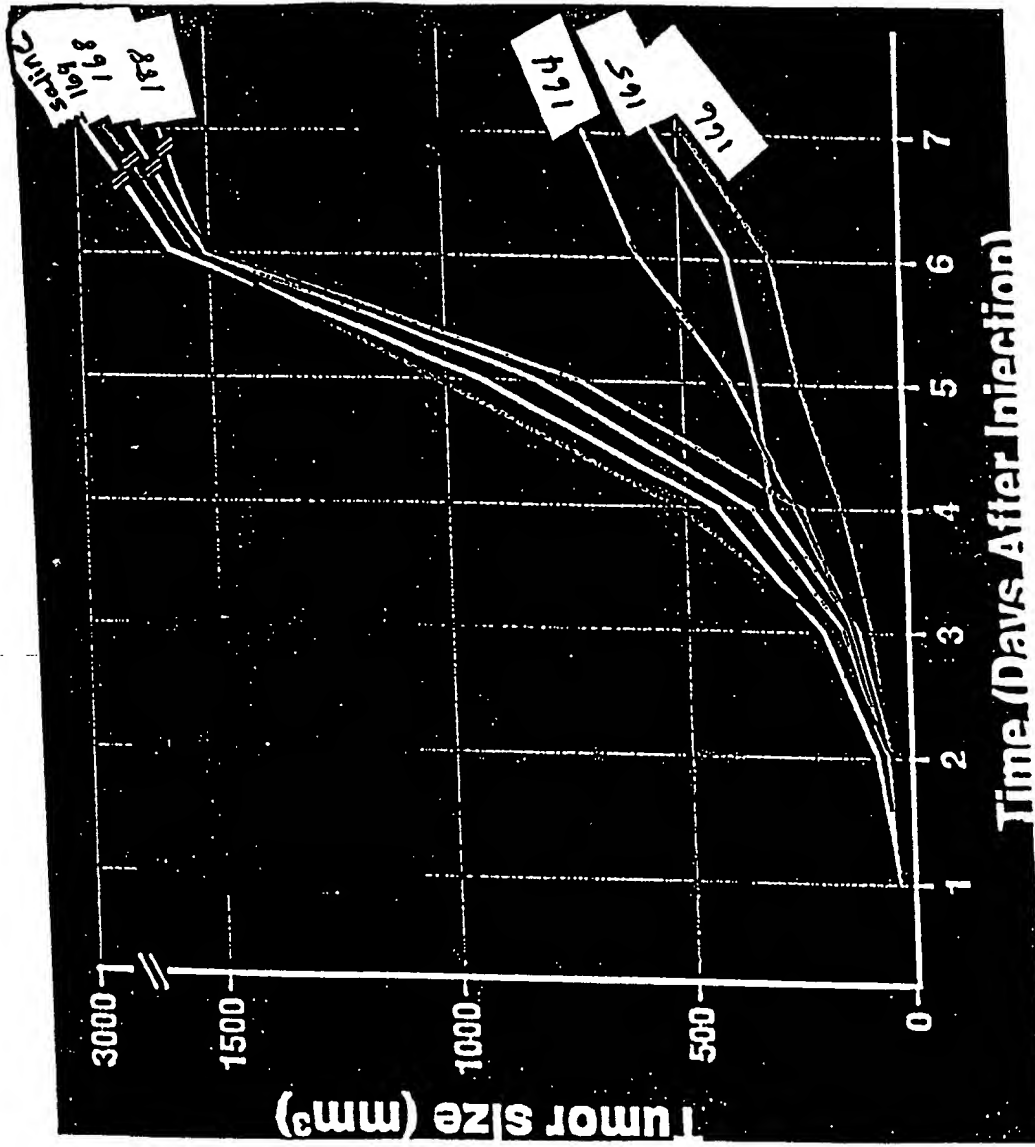


FIG. 1

INTERNATIONAL SEARCH REPORT

Intern nal Application No

PCT/US 98/03003

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C12N15/11 A61K31/70 C07H21/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C12N A61K C07H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 96 16976 A (POLA CHEM IND INC) 6 June 1996 see abstract see SEQ ID 5	1-3, 10, 12, 13, 18, 27-29, 31-33, 35-37
Y	EP 0 490 077 A (FORYOU CORP) 17 June 1992 cited in the application see the whole document -/-	1-38

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents :

A document defining the general state of the art which is not considered to be of particular relevance

E earlier document but published on or after the international filing date

L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

O document referring to an oral disclosure, use, exhibition or other means

P document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

& document member of the same patent family

Date of the actual completion of the international search

23 June 1998

Date of mailing of the international search report

07.07.98

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Andres, S

INTERNATIONAL SEARCH REPORT

Intern 1st Application No

PCT/US 98/03003

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 94 23028 A (HYBRIDON INC ;AGRAWAL SUDHIR (US); TANG JIN YAN (US); PADMAPRIYA A) 13 October 1994 see page 6, line 2 - line 8 see page 12, table I, CMPD C, CMPD J and CMPD K see page 18, line 3 - page 19, line 6 see example 4 see claims 17-28	1-9,27, 28,31, 32,35,36
0,Y	--- LU, Z. ET AL.: "In vivo stability, pharmacokinetics, and metabolism of a ' hybrid ' oligonucleotide phosphorothioate in rats." PROC ANNU MEET AM ASSOC CANCER RES, (MARCH 1995). 36, PAGE 411. ABSTRACT 2450., XP002025691 see abstract & EIGHTY-SIXTH ANNUAL MEETING OF THE AMERICAN ASSOCIATION FOR CANCER RESEARCH, TORONTO, ONTARIO, CANADA, MARCH 18-22, 1995,	1,2, 10-27, 29-31, 33-35, 37,38
A	--- ZHANG, R. ET AL.: "In vivo stability, disposition and metabolism of a " hybrid " oligonucleotide phosphorothioate in rats." BIOCHEMICAL PHARMACOLOGY, (1995 AUG 8) 50 (4) 545-56., XP000644798 see the whole document, especially page 555, last paragraph	1-38
A	--- GALBRAITH, W. ET AL.: "Complement activation and hemodynamic changes following intravenous administration of phosphorothioate oligonucleotides in the monkey" ANTISENSE RESEARCH AND DEVELOPMENT, vol. 4, 1994, US, pages 201-206, XP002025692 cited in the application	
A	--- NESTEROVA, M. & CHO-CHUNG, Y.: "A single injection protein kinase A-directed antisense treatment to inhibit tumour growth" NATURE MEDICINE, vol. 1, June 1995, pages 528-533, XP002025693 cited in the application see the whole document --- -/--	1,26,31, 35

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/03003

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>MONIA, B. ET AL.: "EVALUATION OF 2'-MODIFIED OLIGONUCLEOTIDES CONTAINING 2'-DEOXY GAPS AS ANTISENSE INHIBITORS OF GENE EXPRESSION" JOURNAL OF BIOLOGICAL CHEMISTRY, vol. 268, no. 19, 5 July 1993, pages 14514-14522, XP000576145 see the whole document</p> <p>---</p>	1,10, 12-17
A	<p>PISETSKY, D. & REICH, C.: "STIMULATION OF IN VITRO PROLIFERATION OF MURINE LYMPHOCYTES BY SYNTHETIC OLIGODEOXYNUCLEOTIDES" MOLECULAR BIOLOGY REPORT, vol. 18, no. 3, October 1993, pages 217-221, XP000610055</p> <p>---</p>	
T	<p>ZHAO, Q. ET AL.: "EFFECT OF DIFFERENT CHEMICALLY MODIFIED OLIGODEOXYNUCLEOTIDES ON IMMUNE STIMULATION" BIOCHEMICAL PHARMACOLOGY, vol. 51, no. 2, 26 January 1996, pages 173-182, XP000610208 see the whole document</p> <p>---</p>	1-38
T	<p>WO 96 31600 A (HYBRIDON INC) 10 October 1996 see the whole document</p> <p>---</p>	1-38
T	<p>YU, D. ET AL.: "Hybrid oligonucleotides: Synthesis, biophysical properties, stability studies, and biological activity." BIOORGANIC AND MEDICINAL CHEMISTRY, (1996) 4/10 (1685-1692)., XP000644792 see the whole document</p> <p>---</p>	1-3, 5-10, 12-17
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 98/03003

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

Although claims 35-38 are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound/composition.
2. ☒ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

see FURTHER INFORMATION sheet PCT/ISA/210
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US 98/03003

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 3-9,28,32,36 (complete) and claims 1-2,27,31, 35 (all partially)

Hybrid oligonucleotides for down-regulating PKA R1alpha, composition and methods for using them.

2. Claims: 10-18,29,33,37 (complete) and claims 1-2,27,31, 35 (all partially)

As for subject 1, but concerning the inverted hybrid oligonucleotide.

3. Claims: 19-26,30,34,38 (complete) and claims 1-2,27,31, 35 (all partially)

As for subject 1, but concerning the inverted chimeric oligonucleotide.

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US 98/03003

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Claims 14 to 16 are drawn to oligonucleotides having flanking RIBOnucleotide regions, which is in complete contradiction with claim 10 they depend on. Indeed, claim 10 is drawn to an inverted hybrid oligonucleotide which (as defined in claim 1) has DEOXYribonucleotide flanking regions. Therefore, claims 14 to 16 have been read and searched as having a central ribonucleotidic region flanked by deoxyribonucleotides in conformity with claim 10.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 98/03003

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